I've done it!! I've created the world's first fully-operational molecular computer!!!

Amazing!! How did you account for quantum interference effects...?

But how did you link up all those tiny circuits?

I incorporated them into the design, rather than trying to eliminate them!

No problem - I modified a few enzyme-linking tricks borrowed from the molecular biologists!

And can it do real calculations...?

Can it!? So far it's come up with 15 alternate proofs for Fermat's last theorem!!!

Speed?

I'm estimating it runs at several trillion computations per second!

In fact, at the moment I'm only having one small problem with my molecular computer...

Which is...?

I can't find it again...
Problem solving strategy

- Look through the exam and do the easiest problems first.
- On each problem, you can use the following “fool proof” procedure to solve the problem:
  - Read the problem carefully.
  - If necessary, draw a picture.
  - Identify the physics principles that are involved in the problem.
  - Identify the known values given in the problem and unknowns values you are expect to find.
  - Choose the appropriate equations that can be used to get the unknown you are suppose to find.
  - Count the number of equations and verify that the number of equations is at least equal to the number of unknown quantities that are in the equations.
  - Solve.
Review

• I have selected 12 problems that illustrate the principles that are involved for the 5th-8th problem sets.
• After doing these problems, I will accept requests for additional problems as time allows.
1. A 1000 kg car traveling East at 20 m/s collides with an 800 kg car traveling West at 15 m/s. The cars stick together after the collision. Their final velocity is about

a) 6.7 m/s  
   West

b) 11.1 m/s  
   West

c) 11.1 m/s  
   East

d) 4.4 m/s  
   East

e) 4.4 m/s East
   West

2. A 200 kg cart traveling in the positive x direction with a speed of 12 m/s strikes a stationary 100 kg cart. After this collision, which is totally elastic, the velocity of the 100 kg cart is

a) 4 m/s  

b) 16 m/s  

c) -4 m/s  

d) 0 m/s  

e) 12 m/s
In a popular amusement park ride, a rotating cylinder of radius 2.85 m is set in rotation at an angular speed of 0.35 revolutions per second, as seen above. The floor then drops away, leaving the riders suspended against the wall in a vertical position. What minimum coefficient of friction between a rider’s clothing and the wall is needed to keep the rider from slipping?

3:  A  $2.33 \times 10^{-1}$  B  $2.92 \times 10^{-1}$  C  $3.64 \times 10^{-1}$
D  $4.56 \times 10^{-1}$  E  $5.69 \times 10^{-1}$  F  $7.12 \times 10^{-1}$
G  $8.90 \times 10^{-1}$  H  1.11
4. Some asteroid named "Briggie" has been discovered revolving around the Sun on a circular orbit with a radius of 2.86E+11 m. What is the period of Briggie's orbit? (in years) DATA: The radius of Earth's orbit is 1.50E+11 m.

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5. A rock is dropped from outer space (initial velocity=0) at a radius R from Earth's center. It is recorded moving at a speed 8368 m/s when it strikes the surface of the Earth. What was R? (in m) (Ignore the air resistance felt during the last few miles of the approach to the planet) \( R_{\text{earth}} = 6.38 \times 10^6 \text{ m} \), \( M_{\text{earth}} = 5.98 \times 10^{24} \text{ kg} \). (in m)

A 4.75 \times 10^6   B 5.94 \times 10^6   C 7.42 \times 10^6
D 9.28 \times 10^6   E 1.16 \times 10^7   F 1.45 \times 10^7
G 1.81 \times 10^7   H 2.27 \times 10^7
6. A uniform 10 kg beam is supported at one end by a hinge and at the other by a cable. The cable is attached to the wall to the beam at an angle of 30°. What is the tension in the cable?

a) 9.8 N  

b) 19.6 N  
c) 29.4 N  
d) 39.2 N  
d) 49 N  
e) 58.8 N  
f) 68.6 N  
e) 98 N
7. By pulling her arms inward towards her body, a figure skater is able to change her moment of inertia from 10 kg\(\cdot\)m\(^2\) to 7 kg\(\cdot\)m\(^2\). If her initial angular velocity is 3 rad/s, her final angular velocity will be

a) 2.1 rad/s b) 70 rad/s c) 4.3 rad/s d) 21 rad/s e) 0.7 rad/s
8. Four 2 kg masses are located at the corners of a square with sides 0.5 m long. The moment of inertia of this system of masses about an axis which passes through opposite corners of the square is about

a) 0.25 kg·m²  b) 0.5 kg·m²  c) 1.0 kg·m²  d) 2.0 kg·m²  e) 4.0 kg·m²
9. If 1.0 cubic meters of a building material weighs $6.5 \times 10^4$ N and a column of the material collapses under its own weight if the column is taller than 882 m, what is the compression strength (in Pa) of this material? (the maximum pressure that can be withstood by the material)

A $7.78 \times 10^6$  
B $1.04 \times 10^7$  
C $1.38 \times 10^7$

D $1.83 \times 10^7$  
E $2.44 \times 10^7$  
F $3.24 \times 10^7$

G $4.31 \times 10^7$  
H $5.73 \times 10^7$
An incompressible ideal fluid flows downward through the pipes as shown. The pipe widens from 3 cm diameter at B to 5 cm at A.

- The mass of fluid that passes B in one second is ________________ the mass of fluid that passes A in one second.
  - A  greater than
  - B  less than
  - C  equal to
  - D  CAN NOT BE DETERMINED

- The pressure at B is ________________ the pressure at A.
  - A  greater than
  - B  less than
  - C  equal to
  - D  CAN NOT BE DETERMINED

- The density of the fluid at B is ________________ the density of the fluid at A.
  - A  greater than
  - B  less than
  - C  equal to
  - D  CAN NOT BE DETERMINED

- The magnitude of the velocity of the fluid at B is ________________ the magnitude of the velocity of the fluid at A.
  - A  greater than
  - B  less than
  - C  equal to
  - D  CAN NOT BE DETERMINED
10. A log floats on the surface of a freshwater lake with 40% of its volume below the surface of the water. The density of the log is about

a) 0.8 kg/m³.  b) 1.6 kg/m³.  c) 3.1 kg/m³.  d) 6.2 kg/m³.  e) 12 kg/m³.

f) 25 kg/m³.  g) 50 kg/m³.  h) 100 kg/m³.  i) 200 kg/m³  j) 400 kg/m³.
11. The Mariana trench is located in the Pacific Ocean and has a depth of approximately 11 000 m. The density of sea water is 1025 kg/m³. If a diving chamber were to explore such depths, what force would the water exert on the chamber's observation window (radius = 0.15 m)?

1) $2.5 \times 10^7$ N  
2) $7.8 \times 10^6$ N  
3) $3.3 \times 10^6$ N  
4) $9.4 \times 10^5$ N  
5) $6.2 \times 10^5$ N  
6) $4.7 \times 10^5$ N  
7) $1.0 \times 10^5$ N  
8) $8.6 \times 10^4$ N  
9) $5.1 \times 10^5$ N  
10) $1.2 \times 10^4$ N
quiz

12. A truck can negotiate an icy unbanked circular turn at a much higher speed when it is loaded than when it is empty because it has a higher maximum static friction force.
   - a) True
   - b) False
   - c) Insufficient information to answer
13. A train speeds around a curve with a radius of curvature of 1.41 km. If the acceleration experienced by the passengers is to be less than 0.1 g, find the maximum acceptable speed. (in km/hr) DATA: \( g = 9.81 \, \text{m/s}^2 \)

A 85.7        B 107.1        C 133.9        D 167.4
E 209.2        F 261.5        G 326.9        H 408.6

14. A 2 lb. block on the earth weighs more than a 2 lb. block on the moon.

a) T  b) F
15. A 200 gram meterstick is horizontal and supported at the left and right ends by strings with tensions $T_1$ and $T_2$, respectively, as shown in the figure to the right. An object is suspended 60 cm from the left end of the meterstick. If tension $T_2$ in the right string is about 4.0 N, tension $T_1$ in the left string is about

a) 4.00 N  b) 6.00 N  c) 2.67 N  d) 2.99 N  e) 6.49 N
16. Two isolated objects moving on a flat frictionless surface collide inelastically. The sum of their momenta after the collision is the same as it was before the collision.

17. Consider a turntable which has a constant angular acceleration of $1 \text{ rad/s}^2$ and an instantaneous angular velocity of $1 \text{ rad/s}$. A mass attached to this turntable at a distance of $1 \text{ m}$ from the axis of rotation will experience an instantaneous total linear acceleration of $1 \text{ m/s}^2$.

18. The center of gravity of an object must be physically located somewhere within the material that makes up the object.
19. A motorcyclist starts from rest and maintains a constant linear acceleration of 0.6 m/s². The wheels of the motorcycle have a radius of about 0.5 m. During the first 15 s of motion the wheels rotate about

a) 67.5 rad      b) 7.5 rad      c) 135 rad      d) 4.5 rad      e) 270 rad

20. The magnitude of the torque on a 1.5 m beam exerted by the indicated forces about an axis through point O and perpendicular to the paper is (Note: all forces are in the plane of the paper.)

a) 3 N·m      b) 0 N·m      c) 18 N·m      d) 12 N·m      e) 15 N·m
21. At $t=0$, a wheel of radius 1 meter is at rest and begins rotating with a constant angular acceleration of $2 \text{ rad/s}^2$. After the wheel has rotated $27 \text{ rad}$, the angular velocity is about

a) 10.4 rad/s  

b) 54 rad/s  

c) 729 rad/s  

d) 108 rad/s  

e) 7.4 rad/s
22. A drunk driver strikes a parked car. During the collision the cars become entangled and skid to a stop together. Each car has a total mass of 910 kg. If the cars slide 16.5 m before coming to rest, how fast was the drunk driver going? The coefficient of sliding friction between the tires and the road is 0.35. (in m/s)

a) 2.892   b) 3.846   c) 5.116   d) 6.804

  e) 9.049   f) 12.035  g) 16.007  h) 21.289

23. A baseball has a mass of about 0.17 kg, and it is pitched towards home plate at a speed of about 37 m/s. If the bat exerts an average force of 7300 N for 1.9 ms, what is the final speed of the ball in m/s? (in m/s)

a) 25.21   b) 33.52   c) 44.59   d) 59.30

  e) 78.87   f) 104.90  g) 139.52  h) 185.56
The puck in the figure has a mass of 0.17 kg. Its original distance from the center of rotation is 50 cm, and the puck is moving with a speed of 1.1 m/s in a circle. The string is pulled downward until the center of rotation has moved to r=25 cm. The table is effectively frictionless. What is the work required to pull the puck to the new position? (in J)

A 0.10  B 0.13  C 0.16  D 0.20
E 0.25  F 0.31  G 0.39  H 0.48
The diameter of the main rotor of a single-engine helicopter is 12.2 m. The rotational speed is 450 rev/min. What is the speed of the tip of the large rotor? Give answer as a fraction of the speed of sound, $v_{\text{sound}} = 343$ m/s.

25. A 0.84  B 1.22  C 1.76  D 2.55  
   E 3.70  F 5.37  G 7.79  H 11.29
Consider twins named Bert and Ernie who are visiting a planet named Izzone. Bert is standing at the top of the highest mountain on Izzone, a distance R from the center of the planet. Ernie flies by in a space ship, which is in a stable circular orbit at the same altitude R.

26. If Ernie were to step on a bathroom scale in his space ship, his weight would register as zero.
   a) true  b) false  c) d)

27. Ernie and Bert experience the same acceleration.
   a) true  b) false  c) d)

28. Ernie and Bert feel the same gravitational force but Bert also feels an additional force from the ground.
   a) true  b) false  c) d)

29. If Big Bird were to fly in a circular orbit of radius 3R, Big Bird would experience one third of the gravitational force experienced by Ernie.
   a) true  b) false  c) d)
30. A vicious young gorilla named Donkey Kong swings from a vine and at the bottom of his swing, grabs a football player who he has mistaken for the love of his life. As luck would have it, both Donkey Kong and the linebacker have the same mass. If Donkey Kong starts his swing at rest from an angle of 57 degrees from the vertical, to what final angle do Donkey Kong and his sweetheart ultimately reach on their upward swing? (give answer in degrees)

a) 12.59     b) 14.73      c) 17.24     d) 20.17
e) 23.59      f) 27.61      g) 32.30     h) 37.79

31. A rock is dropped from outer space (initial velocity=0) at a distance of 2.1R_{earth} from the Earth's center. What speed will it have when it reaches the surface of the planet. (Ignore the air resistance felt during the last few miles of the approach to the planet) \( R_{earth} = 6.38 \times 10^6 \text{ m} \), \( M_{earth} = 5.98 \times 10^{24} \text{ kg} \). (in m/s)

a) 871     b) 1263     c) 1831     d) 2655
e) 3849     f) 5581     g) 8093     h) 11735
Dumb Dora slides a bumper car down an icy frictionless hill of height $h$. At the bottom of the hill, she collides head-on with her lifetime companion Brainless Billy, who is at rest in his bumper car. The two cars, including their dimwitted passengers, have equal mass. After the collision the two cars stick together. Their speed after the collision is 20 mph.

▷ If the collision is repeated with an initial height of $2h$, and they still stick to one another, their final velocity will be

32. A 20 mph  B 28.284 mph  C 40 mph  D 80 mph

▷ If the collision is repeated from the original height $h$, but they bounce off each other elastically, Billy’s final velocity will be

33. A 20 mph  B 28.284 mph  C 40 mph  D 80 mph
Race tracks are banked at an angle $\theta$ for a design speed at which friction is not required to steer the car around the curve. If the design speed is 61 m/s, and the radius of curvature is 120 m, what is the banking angle? (in degrees, zero degrees refers to a flat track)

34. A 58.0  B 72.4  C 90.6  D 113.2  E 141.5  F 176.9  G 221.1  H 276.4
Supergirl, who has a weight of 105 lbs, claims that at top speed she has the same momentum as a 5 ton truck moving at 55 mph. What is Supergirl’s top speed? (in mph) (One ton = 2000 lbs)

35. A  3271  B  3826  C  4477  D  5238
    E  6129  F  7170  G  8389  H  9816
36. Containers A, B, and C are filled to the same level with water. The pressure at the bottom of container C equals the pressure at the bottom of containers A and B.

37. Water enters a tube of diameter 4 cm with a velocity of 2 m/s. The water encounters a constriction of diameter 1 cm. Its velocity in the constricted portion of the pipe is about.

a) 1 m/s  
b) 4 m/s  
c) 8 m/s  
d) 16 m/s  
e) 32 m/s  
f) 64 m/s  
g) 128 m/s  
h) 256 m/s  
i) 512 m/s  
j) 1024 m/s
A force of 200 N is applied to a hydraulic jack piston which is 2 cm in diameter. If the piston supporting the load to be lifted by the jack has a diameter of 60 cm, the mass that can be lifted by the jack is about

a) 5.5x10^3 kg  

b) 9.8x10^4 kg  
c) 1.3x10^4 kg  
d) 1.8x10^4 kg  
e) 2.8x10^4 kg  
f) 5.8x10^4 kg  
g) 6.3x10^4 kg  
h) 7.9x10^4 kg  
i) 9.2x10^4 kg  
j) 1.3x10^5 kg
A stainless steel orthodontic wire is applied to a tooth, as shown in the figure above. The wire has an unstretched length of 25 mm and a cross sectional area of 3 mm². The wire is stretched 0.1 mm. Young’s modulus for stainless steel is \(1.8 \times 10^{11}\) Pa. What is the tension in the wire? (in N)

39. A □ 1325  B □ 1497  C □ 1692  D □ 1912  E □ 2160  F □ 2441  G □ 2758  H □ 3117
A car is designed to get its energy from a rotating flywheel with a radius of 2.05 m and a mass of 525 kg. The flywheel is shaped like a pancake and can be considered as a uniform cylinder. Before a trip, the flywheel is attached to an electric motor, which brings the flywheel’s rotational speed up to 4200 rev/min. If the flywheel is to supply energy to the car as would a 9500 Watt motor, find the time (in minutes) the car could run before the flywheel would have to be brought back up to speed.

40. A  90   B  102   C  115   D  130
    E  147   F  166   G  187   H  212
A small Ferris wheel has a moment of inertia of 1.49E+6 kg* m² and is designed to rotate once every 10 seconds. Starting at rest, it undergoes an angular acceleration due to a motor that produces a torque of 1.50E+4 N* m. How many seconds will be required for the Ferris wheel to reach its designed rotational velocity?

41. A 39  B 46  C 53  D 62
   E 73  F 85  G 100  H 117
A solid cylinder \((I = MR^2/2)\) rolls down a hill of height 31 m without slipping. What is the velocity of the cylinder at the bottom of the hill? DATA: \(g=9.80 \text{ m/s}^2\) (in m/s)

42. A○ 10.7  B○ 12.6  C○ 14.7  D○ 17.2
   E○ 20.1  F○ 23.5  G○ 27.6  H○ 32.2
43 Consider a turntable which has a constant angular acceleration of $1 \text{ rad/s}^2$ and an instantaneous angular velocity of $1 \text{ rad/s}$. A mass attached to this turntable at a distance of $1 \text{ m}$ from the axis of rotation will experience an instantaneous total linear acceleration of $1 \text{ m/s}^2$.

44 Mass M moves in a circular path with a constant speed $v$. If the speed of mass M is halved and the radius of the circle is doubled, the angular momentum of this mass will remain the same.
The tension in the vertical supporting cable exceeds the weight of the 100 kg load.
- a) True
- b) False
- c) impossible to determine
A disk with moment of inertia 2 kg·m² is rotating with angular velocity 10 rad/s. If a braking mechanism stops the disk in 0.2 s, the average torque supplied by the brake is

a) 50 N·m  

b) 100 N·m  
c) 5000 N·m  
d) 4 N·m  
e) 25 N·m
47. A uniform 2 kg disk of radius 1.0 m rolls on a horizontal track. If the center of the disk moves with a speed of 10 m/s, the total kinetic energy of the disk is

a) 15 J  b) 50 J  c) 200 J  d) 100 J  e) 150 J
One cubic meter of a building material weighs $6.5 \times 10^4$ N. If a column of the material collapses under its own weight if the column is taller than 1282 m, what is the compression strength (in Pa) of this material? (the maximum pressure that can be withstood by the material)

A $6.09 \times 10^7$  
B $7.12 \times 10^7$  
C $8.33 \times 10^7$  
D $9.75 \times 10^7$  
E $1.14 \times 10^8$  
F $1.33 \times 10^8$  
G $1.56 \times 10^8$  
H $1.83 \times 10^8$
A wooden statue of Elsie the cow is held under water in a swimming pool with a force of 5500 N. If Elsie’s mass is 688.7 kg, what is the density of the statue? (in kg/m$^3$)

49  A  144  B  181  C  226  D  282  
    E  353  F  441  G  551  H  689
A blood vessel is 0.1 m in length and has a radius of $1.5 \times 10^{-3}$ m. Blood flows at a rate of $2.0 \times 10^{-7}$ m$^3$/s through this vessel. Determine the difference in pressure (in Pa) that must be maintained between the two ends of the vessel. ($h=3 \times 10^{-3}$ N$\times$s/m$^2$)

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